

PHYSICS 129 A

Nuclear Physics I

September 23, 2004

Office Hours

Today

12:30 PM - 2:00PM

229 Birge Hall

Some Texts on Nuclear Physics:

Bowler, M. G. (1973) *Nuclear Physics*, Pergamon Press

Cottingham, W. N. and Greenwood, D. A. (1986)

An Introduction to Nuclear Physics, Cambridge Univ. Press

Jelley, N. A. (1990) *Fundamentals of Nuclear Physics*, Cambridge

Krane, H. S. (1987) *Introductory Nuclear Physics*, Wiley

Povh, B. et al, (1993) *Particles and Nuclei*, Springer

Segre, E (1977) *Nuclei and Particles*, Benjamin

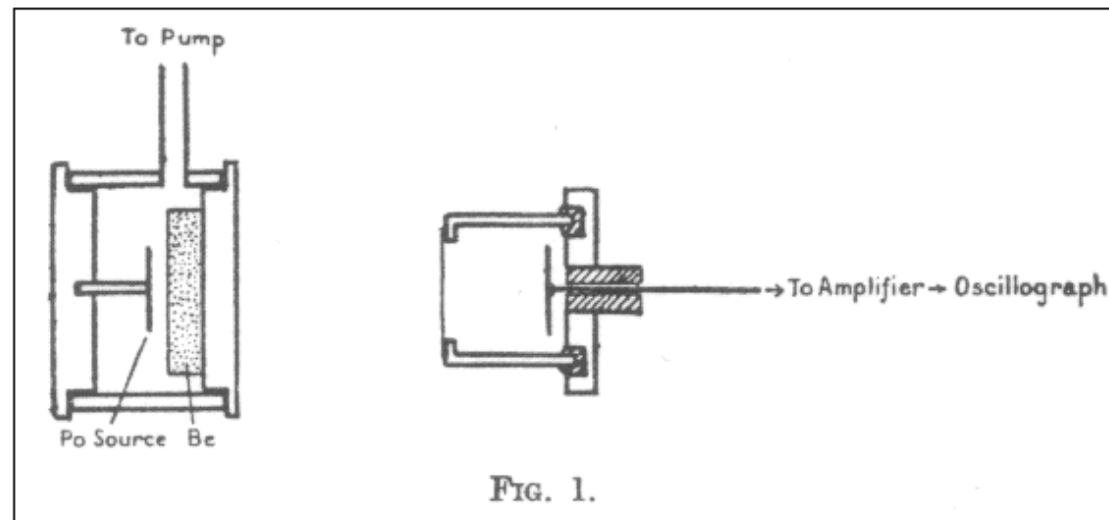
Roy and Nigam (1967) *Nuclear Physics*, Wiley

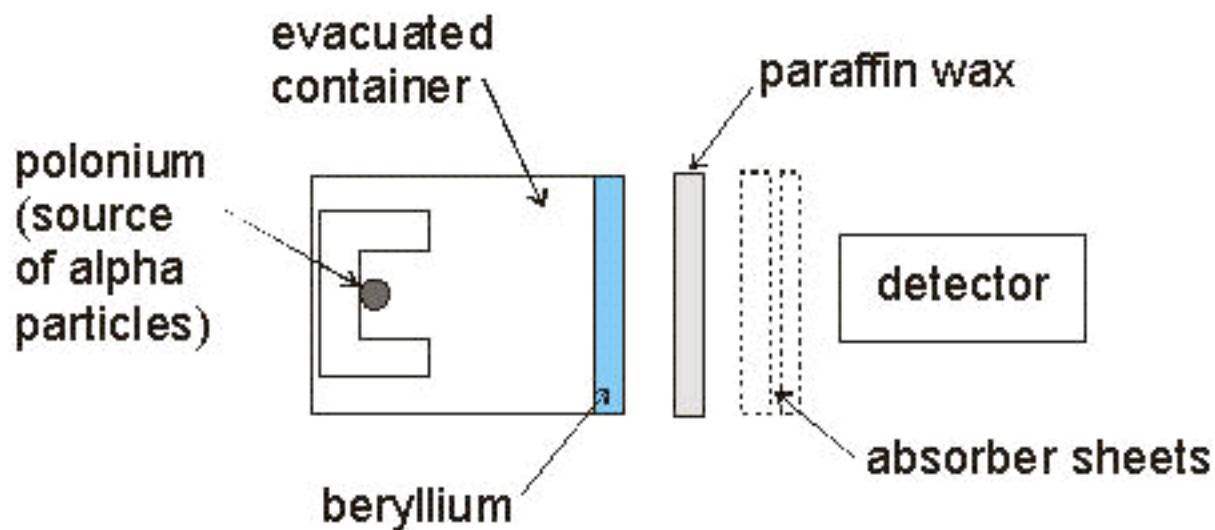
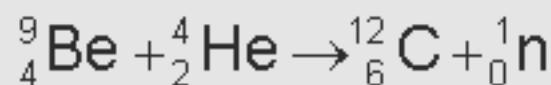
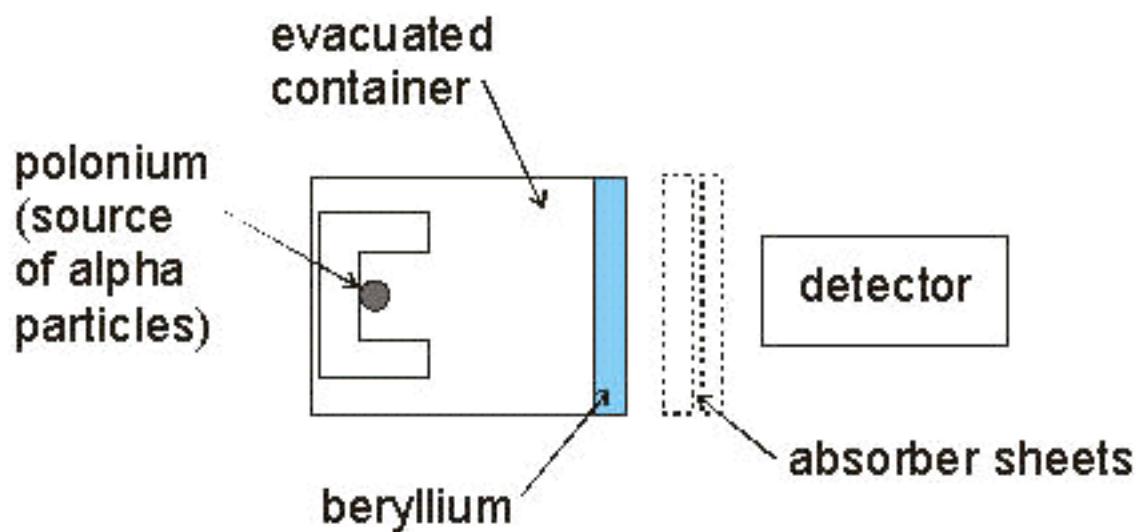
Nuclear Physics

Nuclear Physics really began in the 1930's with Chadwick's discovery of the neutron.

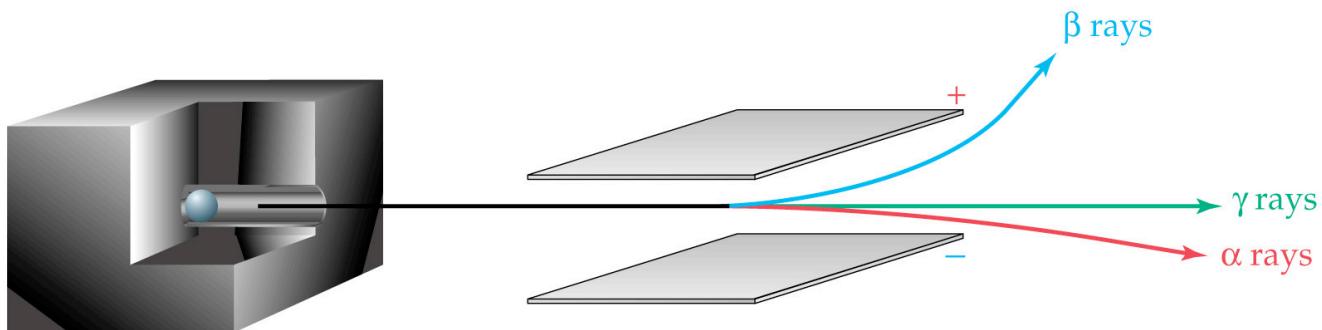


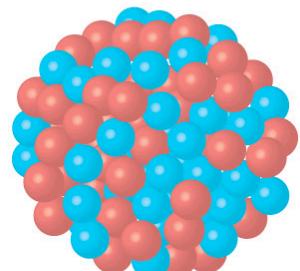
James Chadwick



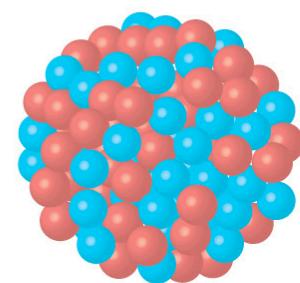


Nuclear Disintegration: Alpha, Beta and Gamma Decay



 $^{238}_{92}\text{U}$

92 protons 
146 neutrons 
238 total

 $^{234}_{90}\text{Th}$

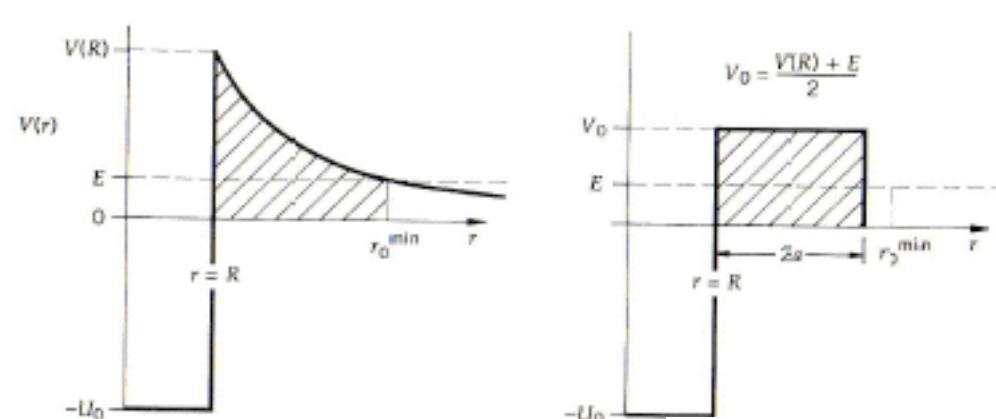
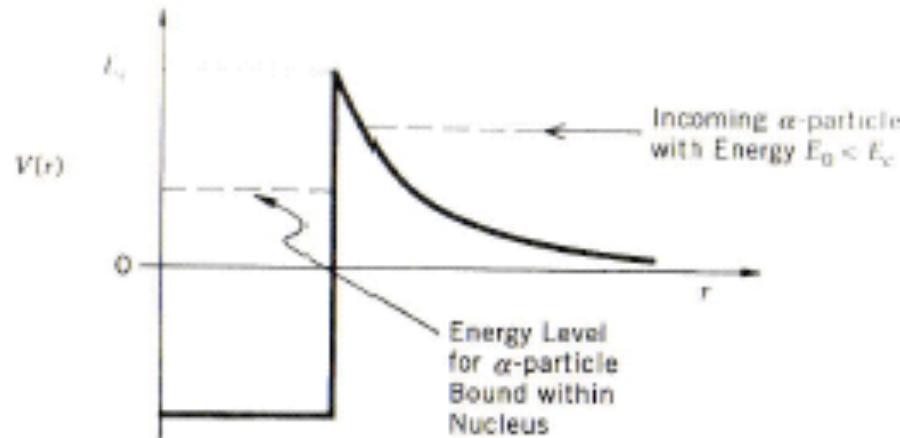
90 protons 
144 neutrons 
234 total

+

 ^4_2He

2 protons 
2 neutrons 
4 total

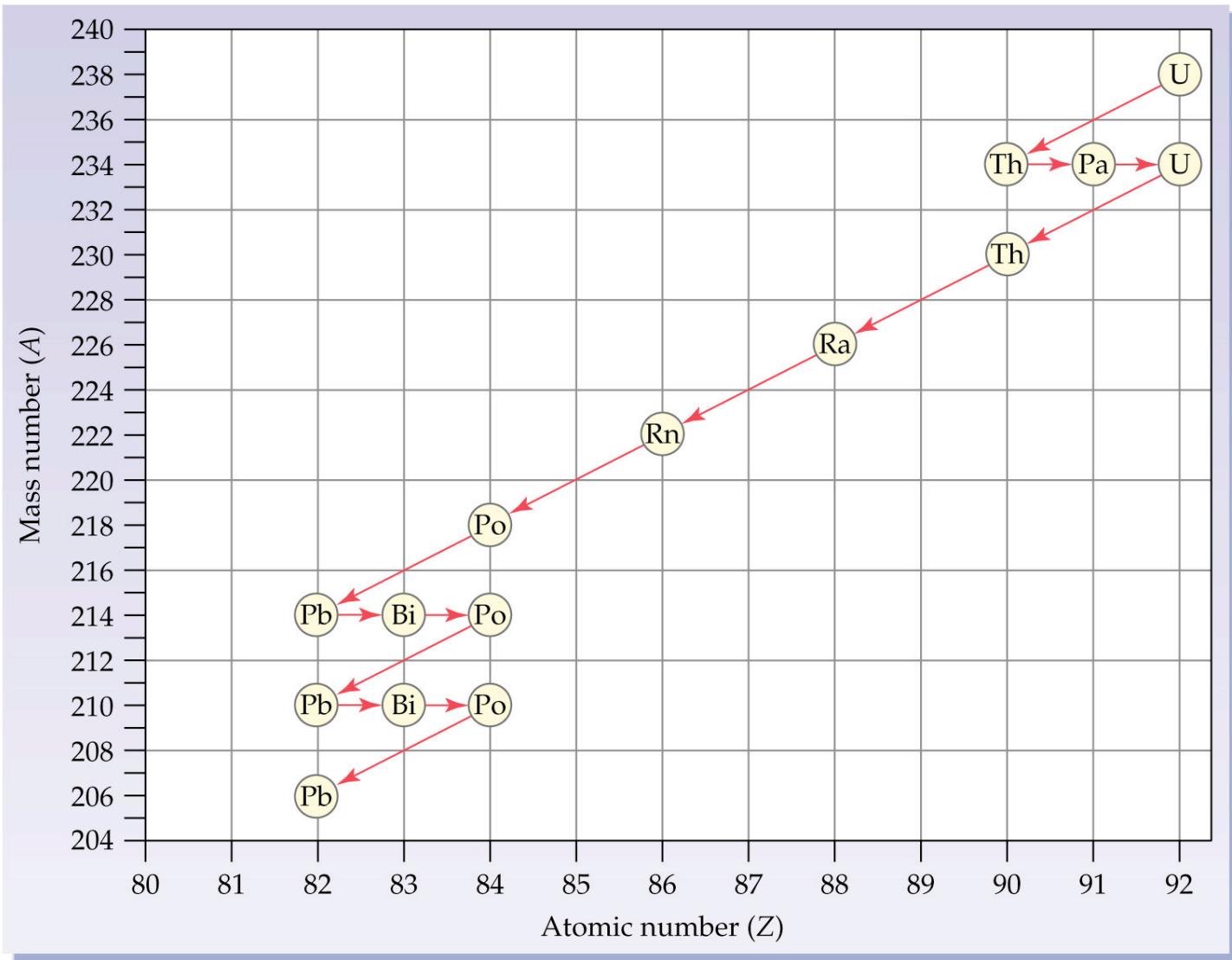
Barrier Penetration

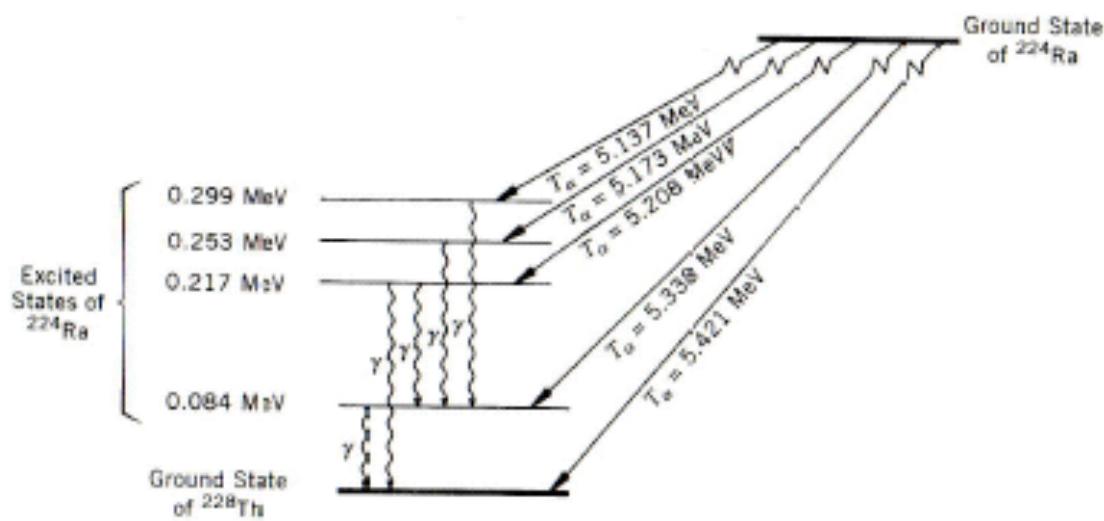
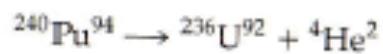


$$T = \frac{[(4k_1 k)/(k_1 + k)^2]}{1 + [(1 + ((\kappa^2 - k_1 k)/\kappa(k_1 + k))^2) \sinh^2 2\kappa a]} \quad (4.15)$$

with

$$\begin{aligned} k_1 &= \left[\frac{2M_\alpha}{\hbar^2} (E + U_0) \right]^{1/2} \\ k &= \left[\frac{2M_\alpha}{\hbar^2} E \right]^{1/2} \\ \kappa &= \left[\frac{2M_\alpha}{\hbar^2} (V_c - E) \right]^{1/2} \end{aligned} \quad (4.16)$$



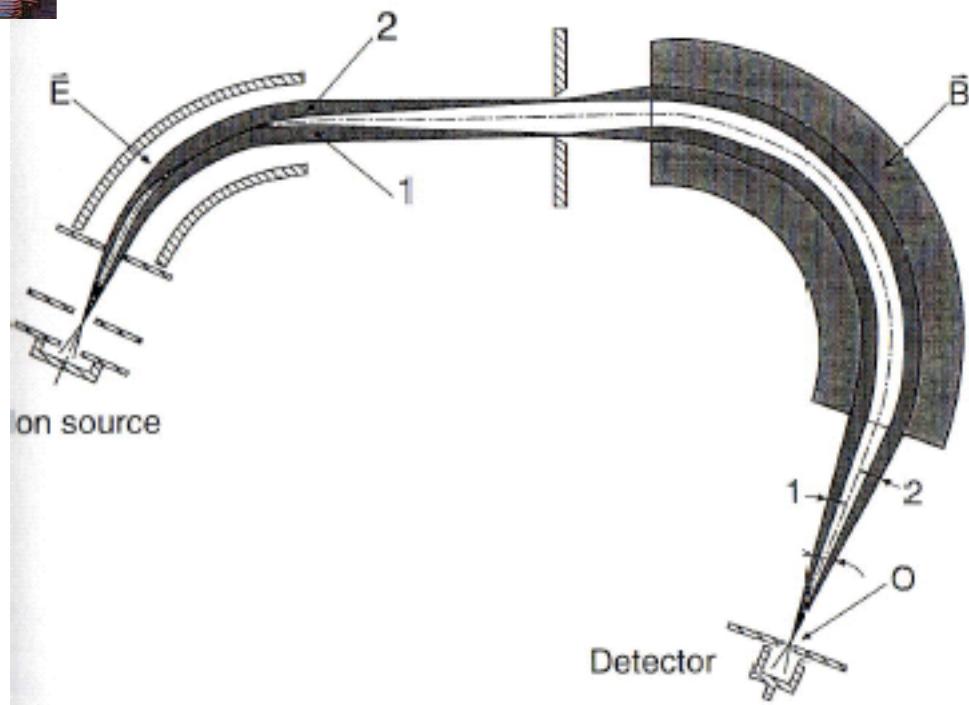


Mass Spectrometers



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Aston



Double Focusing Spectrometer

Notation

N = number of neutrons

Z = number of protons

$A = N + Z$ is the number of nucleons

Usual notation is $^A X$ or $^A X_Z$ or $^A_N X_Z$ or $^A_Z X$ or X^A

Nuclei with same: A - isobars

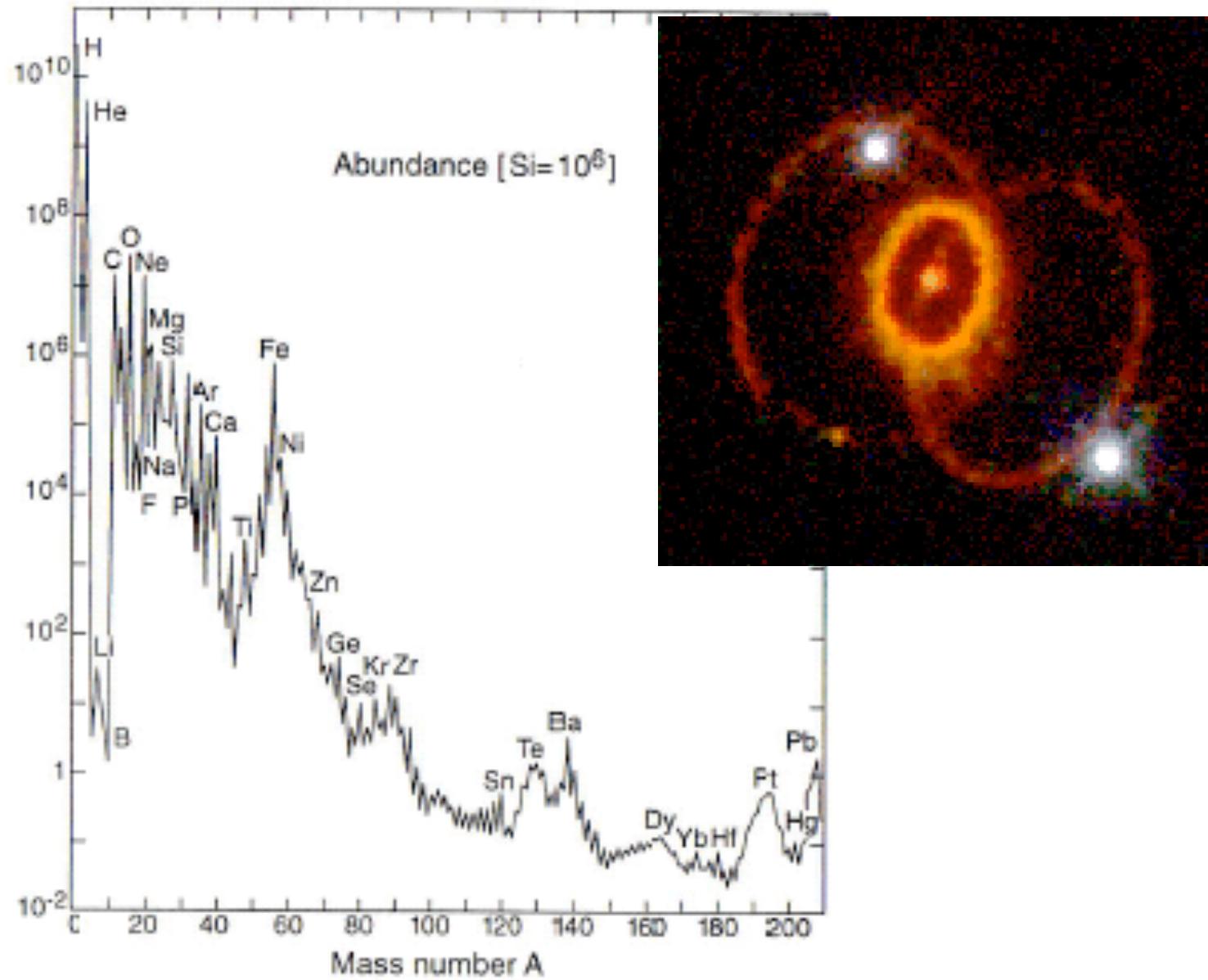
Z - isotopes

N - isotones

Isospin $I_Z = (Z-N)/2$

Nuclear Levels specified by $(J^p, I)^*$

*N.B. Some NP books use T for I and some use $T_z = -I_z$



Solar system abundances of the elements

Bethe-Von Weizsacker semi-empirical mass relation

$$M(A,Z) = Zm_p + (A - Z)m_n - a_v A + a_s A^{\frac{2}{3}} + a_c Z^2 A^{-\frac{1}{3}} + a_a (A - 2Z)^2 A^{-1} + \delta$$

a_v volume term - 15.8 MeV

a_s surface term - 18.0 MeV

a_c coulomb term - 0.72 MeV

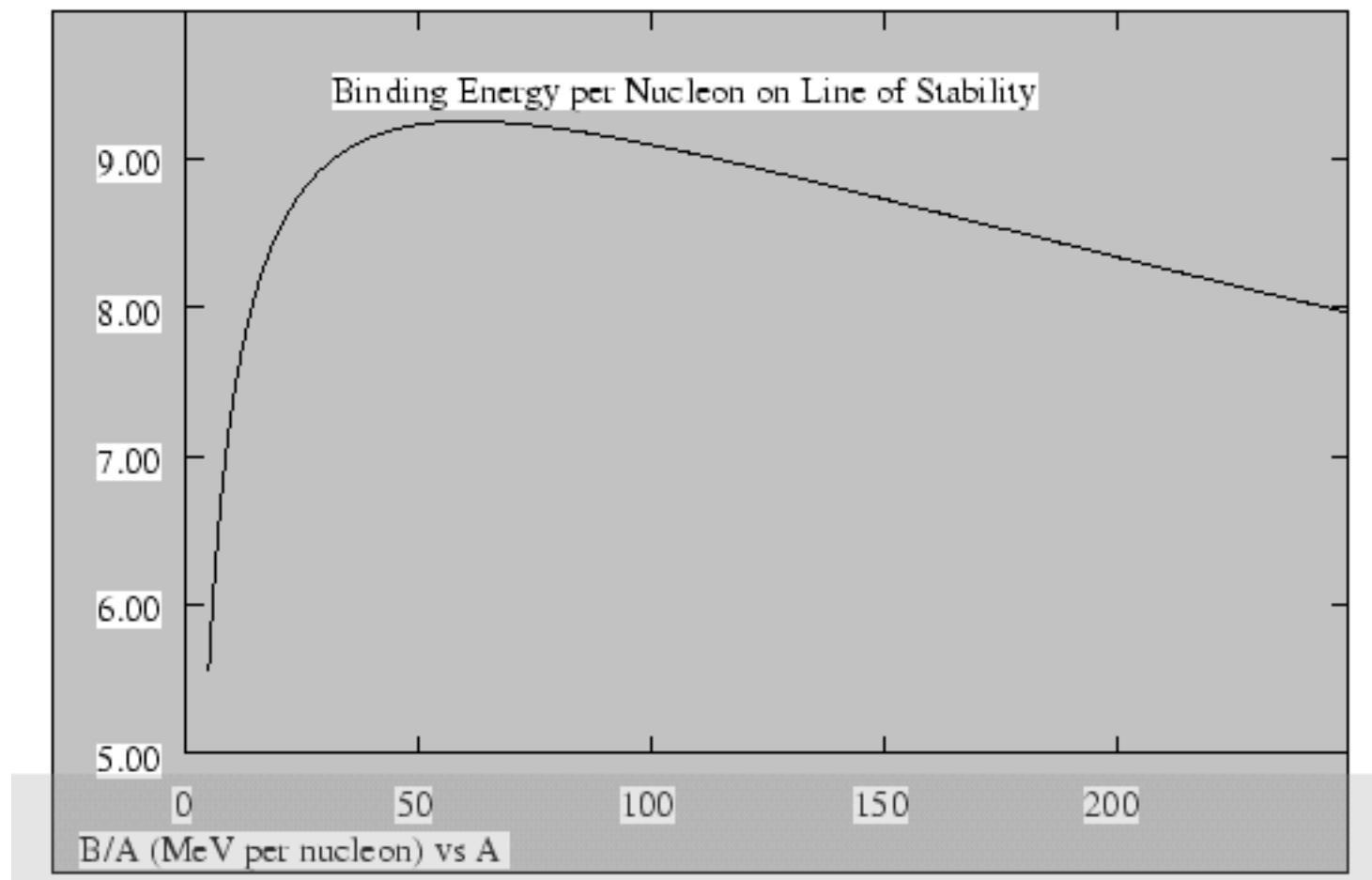
a_a asymmetry term - 23.5 MeV

$\delta = +a_p A^{-3/4}$ (odd-odd) or $-a_p A^{-3/4}$ (even-even))

or 0 (odd-even), $a_p = 33.5$ MeV

$$B(A,Z) = Zm_p + (A - Z)m_n - M(A,Z)$$

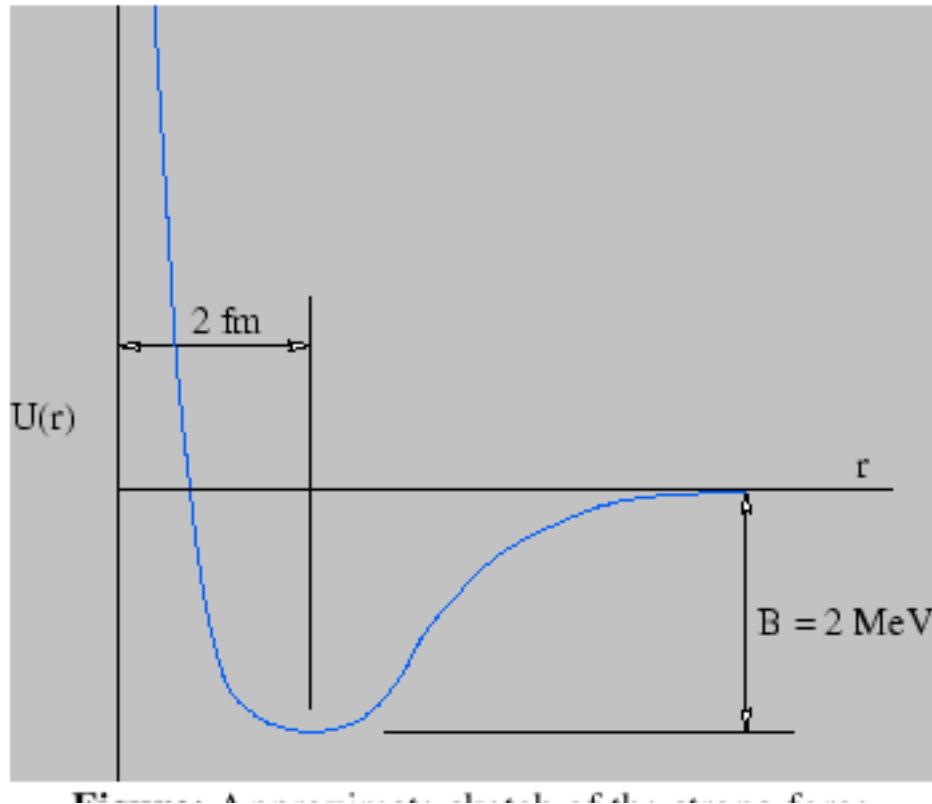
Binding Energy per Nucleon



$$B(Z, A) = a_v A - a_s A^{2/3} - a_c Z^2 / A^{1/3} - a_a (2Z - A)^2 / A$$

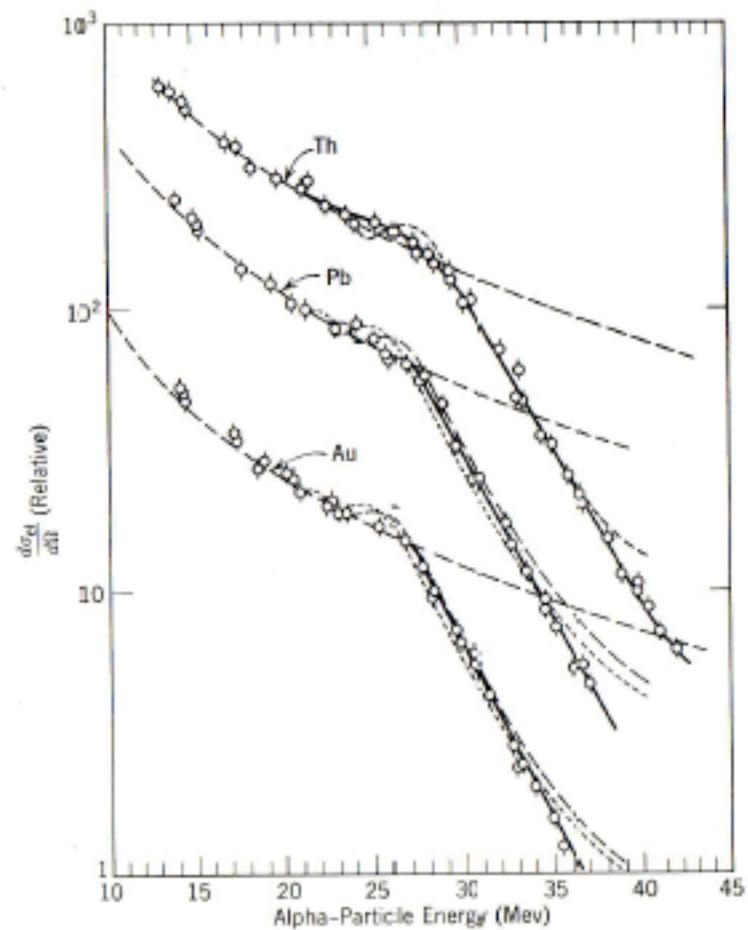
Implications for the form of the Nuclear Force

- *Saturation: expect $B \sim A(A-1)/2$ but $B \sim A \rightarrow$ short range
- *Incompressible: size grows like $A \rightarrow$ repulsive core



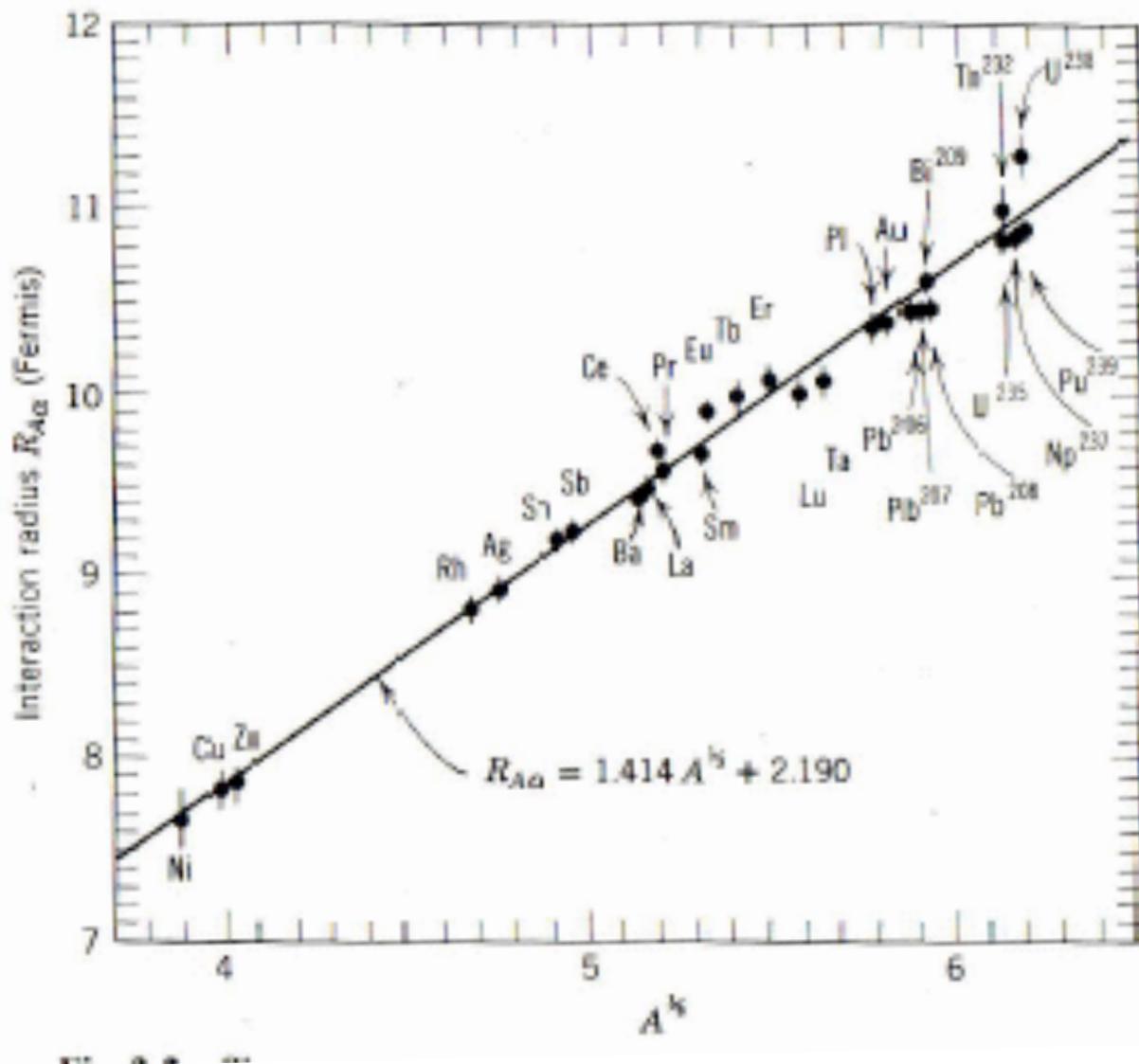
- *Nuclear Force: Short range attraction repulsive core

Sizes of Nuclei



Alpha particle scattering

$$r = r_0 A^{1/3}$$



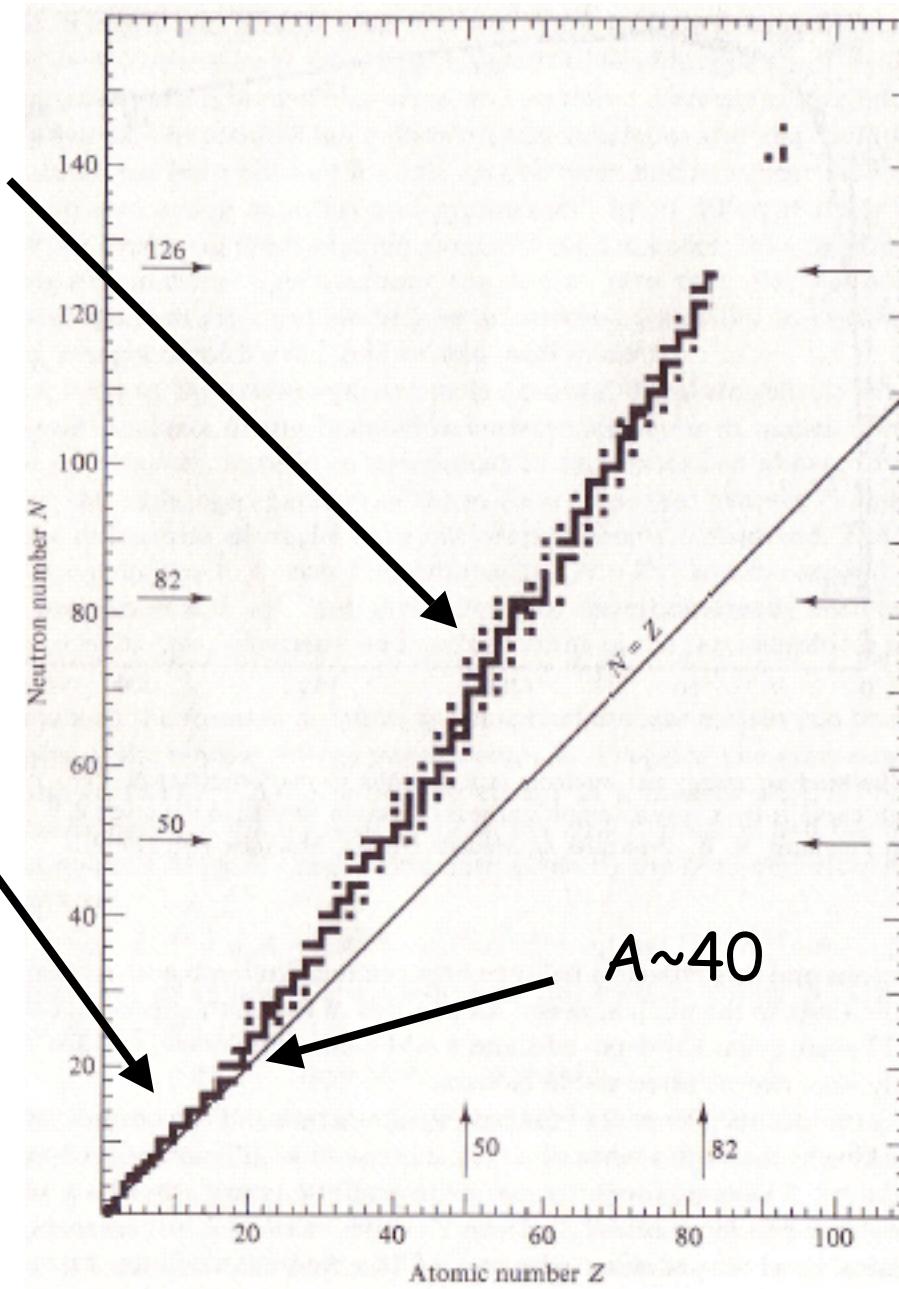
Also:
electron scattering
Ka lines mu-mesonic atoms
Other scattering experiments

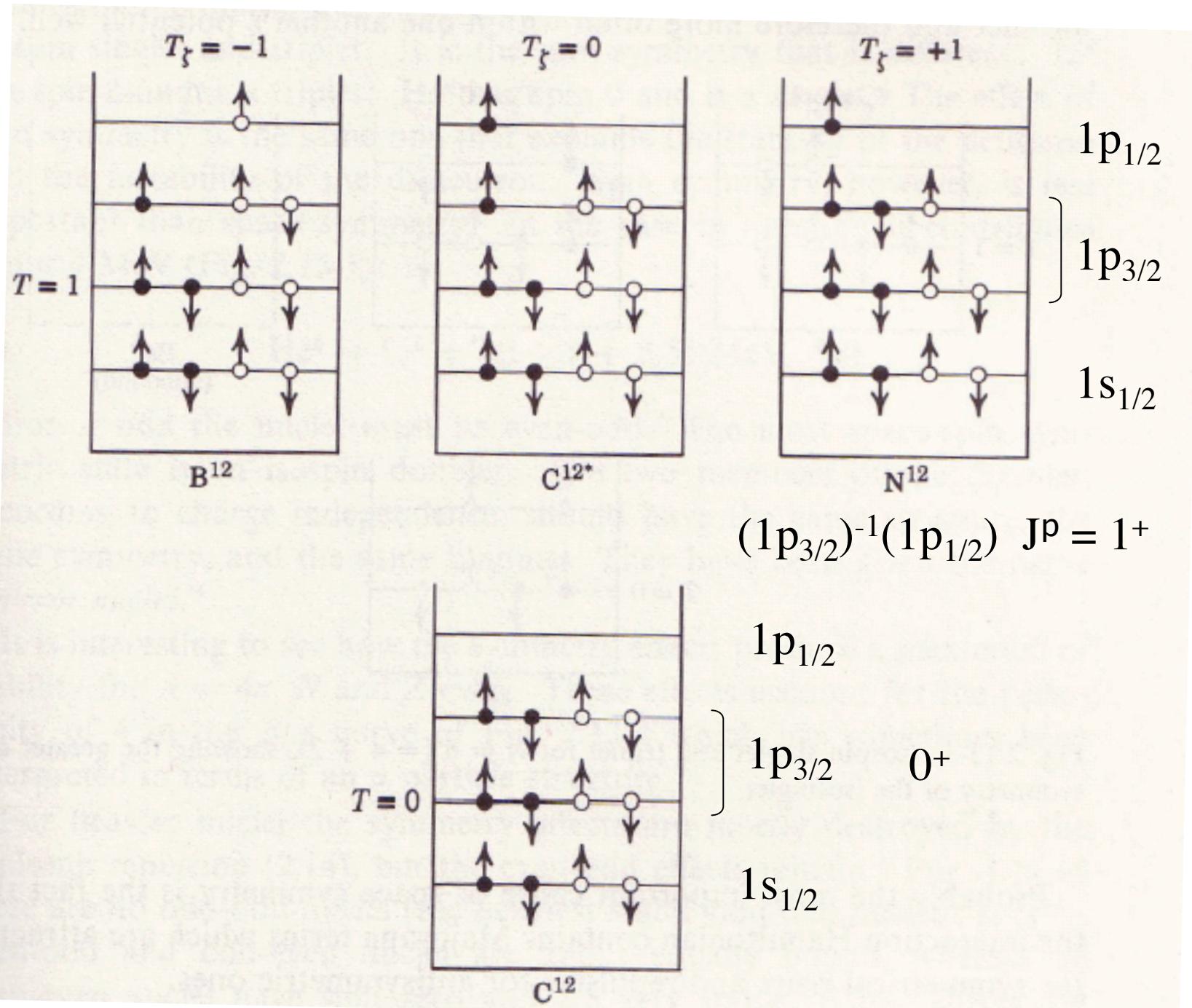
Segre Chart

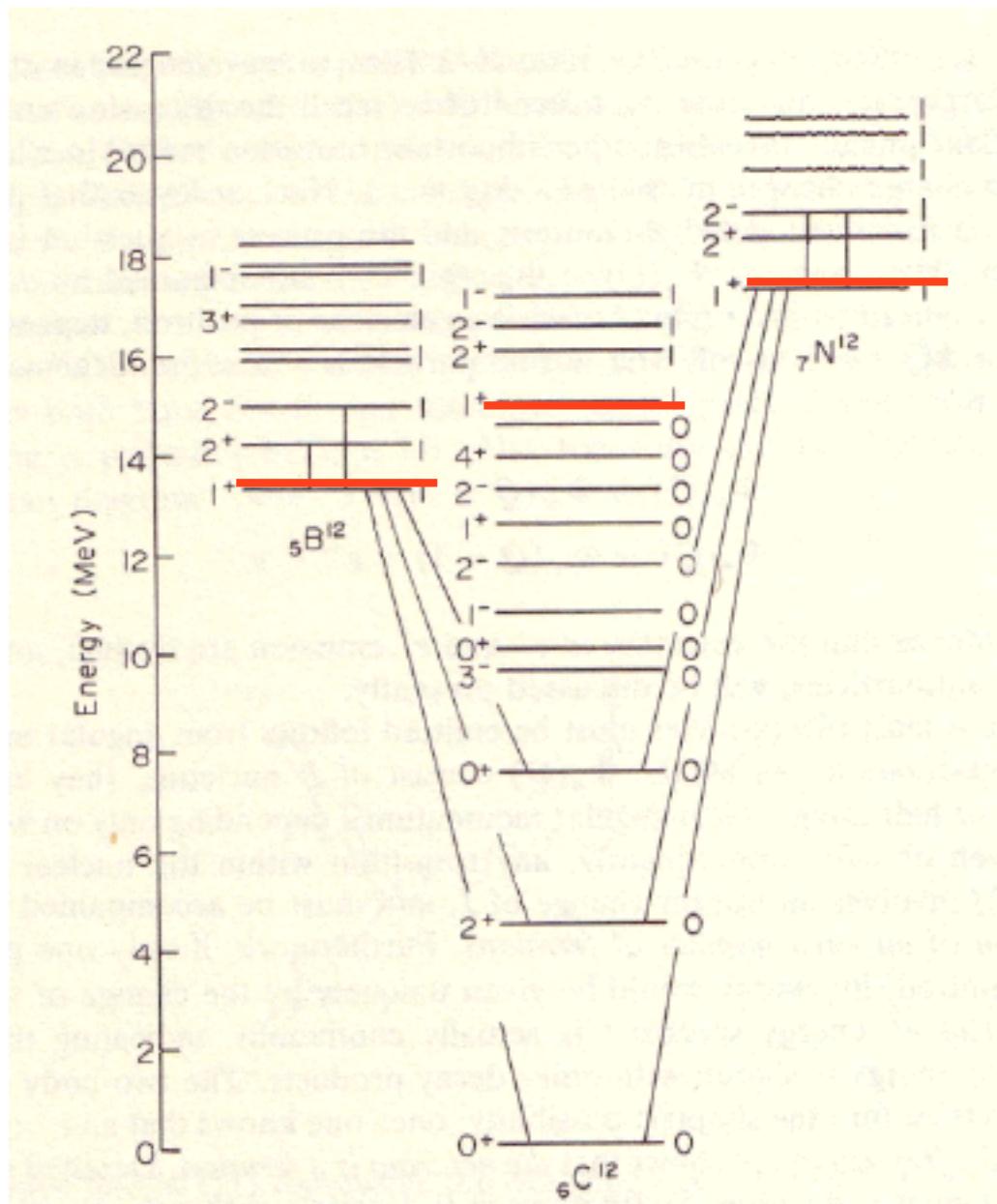
Valley of Stability

$N = Z$ Line

$A \sim 40$

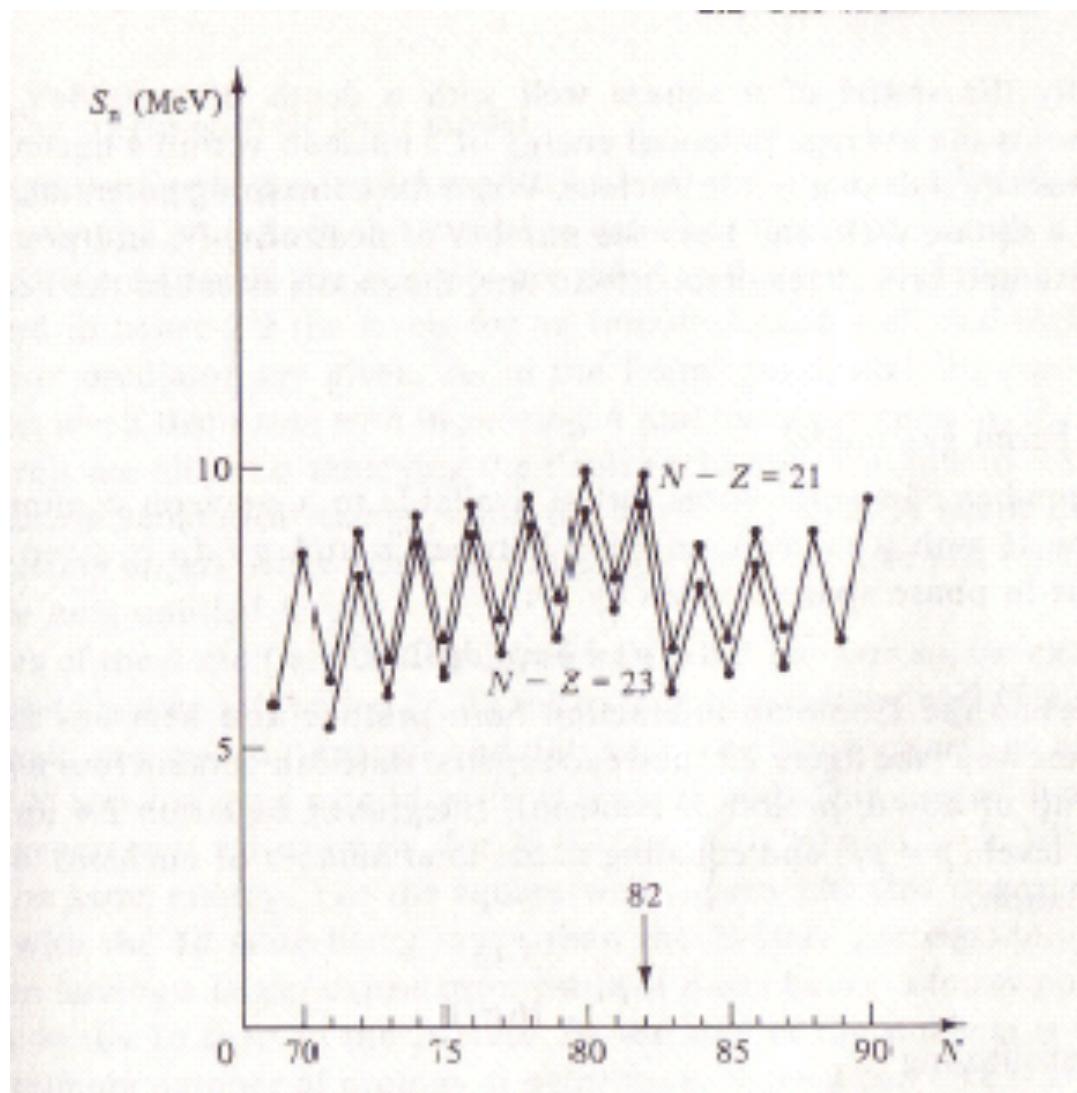






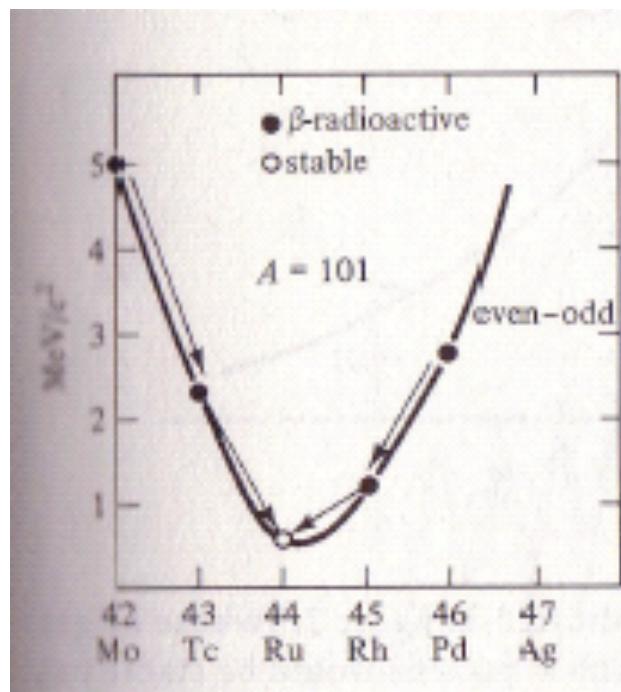
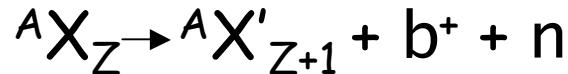
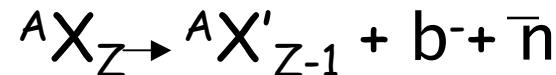
Level Scheme of the Mass 12 Isobars

Neutron Separation Energies



Valley of Stability

Beta Decay:



Double Beta Decay:

